

IN REPLY REFER TO:

United States Department of the Interior
FISH AND WILDLIFE SERVICE

FI-168

JUL 30 1997

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Sacramento Fish and Wildlife Office
3310 El Camino Avenue, Suite 130
Sacramento, California 95821-6340

July 28, 1997

Mr. Lester S. Snow
Executive Director
CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, California 95814

Subject: San Francisco Estuary Institutes's Category III Exotic Species Control
Proposals


Dear Mr. Snow:

The Sacramento Fish and Wildlife Service Office supports the eight proposals submitted by the San Francisco Estuary Institute for exotic species research and control in the Sacramento-San Joaquin Bay-Delta estuary. These eight projects fit within the recommended actions in the Delta Native Fishes Recovery Plan and will help recover listed species in the estuary.

The Service recommends funding of these projects. Such projects are consistent with our mission of preserving fish and wildlife and recovering natural ecosystems and watersheds.

If you have any questions or concerns about the above, contact Robert Pine at (916) 979-2725.

Sincerely,

 Wayne S. White
Field Supervisor

CC: San Francisco Estuary Institute, Richmond, California

a. Project Title: The Impacts of Predation by Exotic Crabs in the San Francisco Estuary

Applicant's Name: The San Francisco Estuary Institute

Principal Investigator: Dr. Andrew Cohen

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b. Project Description and Objectives. The project objective is to gain an understanding of the impacts of the exotic crab species in the San Francisco Estuary through an analysis of their diet. The specific questions to be investigated are:

- Which organisms are preyed on by exotic crabs?
- Do the exotic crabs feed selectively, rather than opportunistically on whatever is abundant?
- Do exotic crabs significantly compete with native crabs for food?
- Has niche displacement or niche narrowing occurred as a result of competition between exotic and native crabs?
- Do exotic crabs exhibit the same diet preferences that they have shown in other regions, indicating that their predatory impacts are relatively predictable?

Diets will be characterized for exotic crabs and sympatric native crabs by analyzing gut contents. Results will be compared with the available food resources as characterized by contemporaneous benthic sampling, with reported pre-invasion diets of native crabs, and with reported diets of these three exotic crabs in other regions of the world. This information will allow an assessment of the impacts of predation by nonindigenous crabs on desired and harmful prey species; of the crabs' prey selectivity; and of the consistency and predictability of an invasive species' predatory impacts across different regions.

c. Approach/Tasks/Schedule. The main tasks to be completed include sampling of crabs, identification and quantification of gut contents, and analysis of the data. Benthic fauna at the collections sites will also be sampled and identified. Analysis will involve comparisons of:

- Crab gut contents and benthic fauna collected at the same site, or IEP or RMP benthic sampling data from nearby stations.
- Gut contents of exotic and native crabs.
- Pre-invasion and post-invasion diets of native crabs.
- Gut contents of these exotic crabs in the Estuary and in other regions of the world.

A final report will be prepared within 24 months of the start of the project. A conference presentation will be made and a journal article submitted based on the results of the study.

d. Justification for Project Funding by CALFED. The San Francisco Bay Estuary is recognized as the most invaded aquatic ecosystem in North America, with more than 200 introduced invertebrates, fish, plants, and micro-organisms. Research conducted to date indicates that the exotic species have caused significant negative impacts on fish and aquatic invertebrate species of the ecosystem. The introduction of exotic species has been identified as a critical factor affecting the health of the Bay/Delta Estuary by water agencies, environmental groups, the CCMP, BCDC, USFWS, CALFED and others. It is one of the seven non-flow factors targeted for research and management by Category III funding, and one of the main stressors listed by the technical teams as appropriate for near-term funding and priorities.

Exotic species have affected all of the priority habitats listed in this RFP. Negative interactions with exotics that have been suggested as impacting priority species include predation (salmon, Delta smelt), competition (splittail), hybridization (Delta smelt), interference with migration (salmon) and creating a contaminant pathway (sturgeon).

Since the late 1980s both the European Green Crab and the Chinese Mitten Crab have invaded the San Francisco Estuary, joining an earlier crab invader, the Atlantic Mud Crab. These crabs have been found or are likely to occur in most of the priority habitats listed for this RFP. These crabs could have a significant impact on Pacific Coast fauna, including both native species and commercially important species, by preying on these organisms or by competing with them for food. Possible interactions of interest that have been suggested by researchers include:

- Predation by Green Crab on commercially-harvested clams, oysters and Dungeness crab.

Executive Summary

- Predation by Green Crab on on harmful exotic organisms such as the Asian clam.
- Competition for food between the Green Crab and native crabs, native shorebirds and possibly native fish.
- Competition for food between the Mud Crab and a native shorecrab.
- Competition for food between Mitten Crab and crayfish, including a commercially harvested species.

e. Budget Costs and Third Party Impacts. The total cost of this project is \$216,100. No third party impacts are anticipated.

f. Applicant Qualifications. The San Francisco Estuary Institute (SFEI) is a non-profit research institute charged with fostering scientific understanding of the Estuary. The Institute conducts or provides science support for four major programs: the San Francisco Estuary Regional Monitoring Program for Trace Substances, the Bay Area Wetlands Ecosystem Goals Project, the Bay Area Watershed Science Program, and the Biological Invasions Program.

SFEI's Biological Invasions Program researches issues of scientific and policy interest related to the introduction of nonindigenous species into marine and freshwater ecosystems. The research program is directed toward five objectives: (1) assisting efforts to prevent future invasions through scientific and policy research on vectors and the control of vectors; (2) developing an effective regional monitoring program to identify new invasions and track the spread of nonindigenous species that are present in the region; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; and (5) developing, prioritizing and assessing methods to control nonindigenous species.

Principal Investigator: Dr. Andrew Cohen holds M. S. and Ph. D. degrees in Energy and Resources from the University of California at Berkeley. He is the author of the 1995 USFWS report on nonindigenous species in the San Francisco Estuary and of papers on other aspects of marine and aquatic invasions. Dr. Cohen has worked on and written about water system planning and economics, public health and contaminants in fish, and environmental mitigation; and has written articles and books for the general public on water and environmental policy and history. His work on invasions in the Estuary was profiled last year in the *New York Times* Science Page, and he was recently nominated to co-chair the Western Regional Panel on Aquatic Nuisance Species. He currently directs the San Francisco Estuary Institute's research program on biological invasions.

Dr. Bruce Thompson received his M. A. at the Moss Landing Marine Laboratory, and his Ph. D. in Biological Sciences from the University of Southern California in 1982, working in benthic marine ecology. He worked at the Southern California Coastal Water Research Project for 11 years prior to joining the staff of SFEI in 1992. His research has included field and laboratory studies of the ecology of benthic communities and species off southern California, and how they are affected by contamination. He was also involved in the development of regional monitoring programs in southern California, and is now the Program Manager for the San Francisco Estuary Regional Monitoring Program at SFEI.

g. Monitoring and Data Evaluation. The draft report will be circulated for external review to regional biologists and to any persons recommended by CALFED. Peer review will also occur when results are submitted for journal publication.

h. Local Support/Coordination with other programs/Compatibility with CALFED objectives. This study will investigate ecological impacts from a key stressor, the introduction of exotic species. The results will also be of value to the many agencies, oyster and clam farmers, crabbers and others concerned about the invasion of the Pacific coast by Green Crab and Mitten Crab.

The Impacts of Predation by Exotic Crabs in the San Francisco Estuary

Principal Investigator: Andrew N. Cohen
San Francisco Estuary Institute
1325 South 46th Street
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Organization Type: Nonprofit research institute
503(c)(3) nonprofit organization

Tax identification number: 94-2951373

Contact person: Andrew N. Cohen

Participants/Collaborators: Bruce E. Thompson

Project Group Type: Services

Introduction: Biological Invasions in the Estuary

The San Francisco Bay Estuary is recognized as the most invaded aquatic ecosystem in North America with more than 200 introduced invertebrates, fish, plants, and microorganisms, some of which have had substantial impacts on native species (Cohen and Carlton 1995). The introduction of nonindigenous species has been identified as a critical factor affecting the health of the Bay/Delta Estuary by water agencies, environmental groups, the CCMP, BCDC, USFWS, CALFED and others. It is one of the seven non-flow factors targeted for research and management by Category III funding, and is one of the main stressors listed by the technical teams as appropriate for near-term funding and priorities. Nonindigenous species have affected all of the priority habitats listed in this RFP. Negative interactions with exotics that have been suggested as impacting priority species include predation (salmon, Delta smelt), competition (splittail), hybridization (Delta smelt), interference with migration (salmon) and creating a contaminant pathway (sturgeon).

The San Francisco Estuary Institute has initiated a research program to address issues of scientific and policy interest related to the introduction of nonindigenous species into marine and freshwater ecosystems. The research program is directed toward five objectives: (1) assisting efforts to prevent future invasions through scientific and policy research on vectors and the control of vectors; (2) developing an effective regional monitoring program to identify new invasions and track the spread of nonindigenous species that are present in the region; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; (5) developing, prioritizing and assessing methods to control nonindigenous species that are present in the region. Proposals in several of these areas are being submitted in the current funding cycle.

Project Description and Approach

The overall project goal is to gain an understanding of the impacts of the three species of exotic crabs in the San Francisco Estuary. The specific objective is an analysis of the diet of these crabs, since predation is likely to be a major source of impact from at least one of them (Cohen *et al.*, 1995). Diets will be characterized for exotic crabs and sympatric native crabs by analyzing gut contents. Results will be compared with the available food resources as characterized by contemporaneous benthic sampling, with reported pre-invasion diets of native crabs, and with reported diets of the three nonindigenous crabs in other regions of the world. This information will allow an assessment of the impacts of predation by nonindigenous crabs on desired and harmful prey species; of the crabs' prey selectivity; and of the consistency and predictability of an invasive species' predatory impacts across different regions.

The specific questions to be investigated are:

- Which organisms are preyed on by exotic crabs?
- Are the exotic crabs feeding selectively, rather than opportunistically on whatever is most abundant?
- Do exotic crabs significantly compete with native crabs for food?
- Has niche displacement or niche narrowing occurred as a result of competition between exotic and native crabs?
- Do exotic crabs exhibit the same diet preferences that they have shown in other regions, indicating that their predatory impacts are relatively predictable?

The main tasks to be completed include sampling of crabs, identification and quantification of gut contents, and analysis of the data, as described below. Benthic fauna at the collections sites will also be sampled and identified.

Sampling. Crabs will be collected by several methods:

- By otter trawl. EBRPD has offered to collect crabs for us from their near-shore sampling.
- In bait-scented traps, consisting of double-ended fyke traps baited with punctured cans of catfood. Preliminary work indicates that this method traps crabs without filling their stomachs with bait, which renders them useless for gut contents analysis.
- By beach seine.
- By hand.
- By excavating burrows.
- As bycatch of commercial shrimp fishermen. Several commercial shrimpers have offered to help in this way, and discussions with CDFG indicated that specific permits could be provided for this method of collection.

Crabs will be killed at the collection site as soon as possible after collection, and their size, sex, moult stage (based on shell color and hardness), chelae condition, limb loss and degree of epizoic fouling recorded. Cardiac stomachs (anterior stomach or foregut) will be removed whole, their degree of fullness recorded, and fixed in formalin in labelled vials. Selected crab carapaces will be retained for closer examination and identification of epizoics. Where possible, benthic fauna will be sampled at collection sites.

Identification. In the laboratory each cardiac stomach will again be estimated for degree of fullness, then opened and its contents rinsed into a gridded glass petri dish and examined under a binocular dissecting microscope. Contents will be identified to the lowest taxon possible. Each type of food item will be recorded and scored for percent of volume and (where appropriate) minimum number of individuals present. To aid in identification, a reference collection of benthic fauna from near the crab collection sites will be assembled with reference samples of whole intact organisms, dissected parts of organisms, and crushed parts of organisms. Keys to parts of organisms found in the crabs will be developed as needed.

Analysis

After data entry, program algorithms will be developed to perform manipulations on the data (funds are included in the proposal for a system analyst to assist with this task). Taxa identified in the cardiac stomachs of each species of crab will be calculated as percent volume and as percent frequency of occurrence by sex, by size class, by season, by location and by other criteria as may be suggested by the data. The similarity in composition of crab gut contents and benthos will be determined with an Index of Relative Importance, to assess the crabs' prey selectivity. Comparisons will also be made with IEP or RMP benthic sampling data for nearby stations. The similarity of gut contents of exotic and sympatric native crabs will be compared to assess the possibility of competition over food. The reported pre-invasion and sampled post-invasion diets of native crabs will be compared for evidence of niche displacement or narrowing. Gut contents of exotic crabs will be compared to reported contents from studies on the same species in other regions to assess the similarity of diet across regions.

Location/Geographic Boundaries

This research will be conducted in those parts of the Estuary where the exotic crabs are found, and may be applicable to other areas where the crabs are found or may spread. The Mitten Crab has spread from the Bay up through the Delta, and seems likely to spread throughout the Central Valley. The Green Crab has spread from the Bay up through Carquinez Strait and north along the coast into Oregon; it is possible that it will also enter Suisun Bay at times (Cohen *et al.*, 1995). The Mud Crab ranges mainly from around Carquinez Strait up through the Delta, but is also found in other brackish waters in the Estuary, and in other estuaries along the coast.

Expected Benefits

Stressors. This project focusses on certain exotic species as potential stressors on prey populations and on food competitors.

Priority Habitats. Priority habitat types where the exotic crabs have been found or are likely to occur are:

- Tidal perennial aquatic habitat—Mitten Crab, Mud Crab
- Seasonal wetland and aquatic habitat—Mitten Crab
- Instream aquatic habitat—Mitten Crab
- Shaded riverine aquatic habitat—Mitten Crab (occasionally)
- Saline emergent wetlands habitat (tidal)—Green Crab, Mitten Crab, Mud Crab
- Midchannel islands and shoal habitat—Mitten Crab, Mud Crab
- North Delta agricultural wetlands—Mitten Crab

Benefits. The information developed by this project on the existing and potential impacts of these common invasive crabs, and on the predictability of impacts in new regions, will be useful to those involved in decisions about the passage or

implementation of regulations intended to reduce introductions of exotic organisms, and in decisions about efforts to control these organisms. Interested parties would include clam and oyster farmers, commercial and noncommercial crab, crayfish and clam harvesters, and bird watchers, since clams, oysters, crabs, crayfish and birds may suffer from predation or competition with these crabs; the shipping, aquaculture, live-seafood-importing, bait-importing and aquarium industries whose activities sometimes transport crabs and other exotic species; refuge managers and environmental groups seeking to protect native biodiversity; and lawmakers and citizens concerned with these issues.

Background and Biological/Technical Justification

Both the European Green Crab *Carcinus maenas* and the Chinese Mitten Crab *Eriocheir sinensis* have invaded the San Francisco Estuary since the late 1980s, joining an earlier crab invader, the Atlantic Mud Crab *Rhithropanopeus harrisii* (Cohen *et al.*, 1995; Cohen, 1995; Cohen and Carlton, 1995). These crabs could have a significant impact on Pacific Coast fauna, including both native species and commercially important species, by preying on these organisms or by competing with them for food. Possible interactions of interest that have been suggested by researchers include:

- Predation by *C. maenas* on commercially-harvested clams, oysters and Dungeness crab *Cancer magister* (Cohen *et al.*, 1995; Grosholz and Ruiz, 1995).
- Predation by *C. maenas* on harmful exotic organisms such as the Asian clam *Potamocorbula amurensis* (Cohen *et al.*, 1995).
- Competition for food between *C. maenas* and native crabs, including Dungeness and Rock crab (Cohen *et al.*, 1995; Grosholz and Ruiz, 1995).
- Competition for food between *C. maenas* and native shorebirds and possibly native fish (Grosholz and Ruiz, 1995).
- Competition for food between *R. harrisii* and the native shorecrab *Hemigrapsus oregonensis*, with which it shares both habitat and habits (Jones, 1940; Jordan, 1989).
- Competition for food between *E. sinensis* and crayfish, including the commercially harvested *Pacifastacus leniusculus* (Hieb, 1997).

Work to date and other studies

Carcinus maenas. Working with the San Francisco Bay population, we (Cohen *et al.*, 1995) conducted some preliminary examination and identification of gut contents and laboratory experiments on prey selection in 1991-1994. Grosholz and Ruiz (1995) have done more extensive work with the Bodega Harbor population, including field enclosure experiments and other work. We (Cohen *et al.*, 1995) provided an extensive review and summary of gut contents analyses, laboratory prey selection experiments, field enclosure experiments and field observations of *C. maenas*' diet and feeding behavior from work done in Europe, eastern North America and South Africa, finding that:

- *C. maenas* has been shown to consume an impressive variety of prey items, including organisms from at least 104 families and 158 genera in 5 plant and protist and 14 animal phyla.
- Dominant types of prey items as determined by gut contents analyses vary widely between different regions.
- Some workers have described *C. maenas* as opportunistically feeding on whatever is available, but many experiments have shown it to be selective with regard to prey species and prey size.
- The selection of prey size and sometimes prey species varies with the crab's size, color (indicative of moult stage) and sometimes sex, which may in turn be explained by differences in chela shape, size or strength.

In contrast to our findings, Grosholz and Ruiz (1996) reviewed the literature and concluded that *C. maenas*' diet is similar in all parts of the world and suggested that its diet in future invaded regions is therefore predictable. Both Cohen *et al.* (1995) and Grosholz and Ruiz (1996) discuss potential Pacific Coast impacts from *C. maenas*' feeding.

Eriocheir sinensis. There have been no gut contents analyses done of *E. sinensis* on the Pacific Coast. Thiel (1938, reported in Hoestland, 1948) found two-thirds of the gut contents of *E. sinensis* in Germany to consist of vegetable matter; the animal material mainly consisted of annelid worms, snails, *Daphnia*, amphipods, shrimps and insects. In the Sacramento-San Joaquin Delta, *E. sinensis* have been reported as frequently stealing the bait used by sport anglers, including shrimp, gobies and threadfin shad.

Rhithropanopeus harrisi. Pisciotto (1978) examined gut contents of a few *R. harrisi* from Coos Bay, Oregon and found sand, algae and part of a crab carapace. Jordan (1989), in examining interactions between *R. harrisi* and the native shorecrab *Hemigrapsus oregonensis* from Coos Bay, found in the laboratory that adult *H. oregonensis* consumed smaller *R. harrisi*, but that *R. harrisi* did not consume *H. oregonensis*.

Proposed Scope of Work

- 1) Collect exotic crabs and sympatric native crabs from the Estuary. Examine, identify and quantify gut contents.
- 2) Where possible, collect and identify benthic fauna (potential prey items) from crab collection sites.
- 3) Compare:
 - Crab gut contents to benthic fauna collected at the site, or to IEP or RMP benthic sampling data from nearby stations.
 - Gut contents of exotic and native crabs.
 - Pre-invasion and post-invasion diets of native crabs.
 - Gut contents of exotic crabs in the Estuary and in other regions of the world.

The deliverables will be a progress report to CALFED at the end of the first year; a final report to CALFED on the project's findings; and an article submitted to a peer-reviewed journal. The results of the study will also be disseminated by presentation at a scientific conference.

Monitoring and Data Evaluation

The draft report will be submitted to the contract manager and to appropriate regional biologists for external review and comment. In addition, persons recommended by CALFED will be asked to review the draft. The journal submission will also be subject to peer review.

Implementability

The investigators will obtain appropriate scientific collecting permits. There are no anticipated implementation issues.

Literature Cited

- Carlton, J. T. & A. N. Cohen. In press. Episodic global dispersal in shallow water marine organisms: The case history of the European green crab *Carcinus maenas*. *J. Biogeogr.*
- Cohen, A. N. 1995. Chinese mitten crabs in North America. *Aquat. Nuisance Species Digest* 1(2):1, 8.
- Cohen, A. N. & J. T. Carlton. 1995. *Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta*. Washington DC: U. S. Fish and Wildlife Service.
- Cohen, A. N. & J. T. Carlton. 1997. Transoceanic transport mechanisms: The introduction of the Chinese mitten crab *Eriocheir sinensis* to California. *Pac. Sci.* 51(1): 1-11.
- Cohen, A. N., J. T. Carlton & M. C. Fountain. 1995. Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay, California. *Mar. Biol.* 122: 225-237.
- Grosholz, E. D. & G. M. Ruiz. 1995. Spread and potential impact of the recently introduced green crab, *Carcinus maenas*, in central California. *Mar. Biol.* 122(2):239-247.
- Grosholz, E. D. & G. M. Ruiz. 1996. Predicting the impact of introduced marine species: lessons from the multiple invasions of the European green crab *Carcinus maenas*. *Biol. Conserv.* 78: 59-66.
- Hieb, K. 1997. Chinese mitten crabs in the Delta. *IEP Newsletter* 10(1): 14-15.
- Hoestland, H. 1948. Recherches sur la biologie de l'*Eriocheir sinensis* en France (Crustacé brachyoure). *Ann. Inst. Oceanogr. Monaco* 24(1): 1-116.
- Jones, L. L. 1940. An introduction of the Atlantic crab into San Francisco Bay. *Proc. 6th Pac. Sci. Cong.* 3: 485-486.
- Jordan, J. R. 1989. Interspecific interactions between the introduced Atlantic crab *Rhithropanopeus harrisi* and the native estuarine crab *Hemigrapsus oregonensis* in Coos Bay, Oregon. M. S. Thesis, University of Oregon, Eugene, Oregon.
- Pisciotta, R. J. 1978. The biology of an introduction: *Rhithropanopeus harrisi*. M. S. Thesis, University of Oregon, Eugene, Oregon.
- Thiel, H. 1938. Die allgemeinen Ernährungsgrundlagen der chinesischen Wollhandkrabbe (*Eriocheir sinensis* H. Milne-Edwards) in Deutschland, insbesondere im weiteren Sinne. *Mitt. Hamb. Zool. Mus.* 47: 50-64.

Budget Tables

Year 1	Direct Hours	Direct Salary & Benefits	Overhead	Service Contracts	Other Direct Costs	Total Cost
Andrew Cohen	240	14,004	7,282			21,286
Bruce Thompson	40	2,694	1,401			4,095
Systems Analyst	20	950				970
Technician	1,460	36,777	19,124			55,902
Intern	800	8,920	4,638			13,558
Equipment					3,500	3,500
Supplies					2,180	2,180
Travel					1,200	1,200
Taxonomic Consultants				2,000		2,000
Miscellaneous					800	800
TOTAL		63,345	32,446	2,000	7,680	105,491

Year 2	Direct Hours	Direct Salary & Benefits	Overhead	Service Contracts	Other Direct Costs	Total Cost
Andrew Cohen	320	19,606	10,195			29,801
Systems Analyst	20	997	519			1,516
Technician	1,460	38,616	20,080			58,697
Intern	800	9,366	4,870			14,236
Equipment						0
Supplies					2,290	2,290
Travel					2,180	2,180
Taxonomic Consultants				1,050		1,050
Miscellaneous					840	840
TOTAL		68,585	35,664	1,050	5,310	110,609

Budget Explanation

(assumes a 5% increase in rates in Year 2)

	<u>Year 1</u>	<u>Year 2</u>
<u>Equipment</u>		
large crab traps 20 @ \$50	1,000	
small crab traps 20 @ \$25	500	
nets	500	
storage cabinet for reference collection	<u>1,500</u>	
SUBTOTAL - EQUIPMENT	3,500	
<u>Supplies</u>		
lab supplies		
glassware		
3 cases of shell vials	450	470
asst screw-top jars	150	160
2 cases of screwtop vials	300	315
misc. glassware	200	210
dissecting tools	100	105
reagents	200	210
office supplies—misc.	200	210
field supplies		
misc. field equipment	100	105
bait, estimated at \$0.50/trap x 40 traps		
x 2 sets/d x 2 d /mo x 6 mo	<u>480</u>	<u>505</u>
SUBTOTAL - SUPPLIES	2,180	2,290
<u>Travel</u>		
Bay Area		
mileage 100 mi/wk x 40 wk @ \$0.30/mi	1,200	1,260
to conference to present paper		
one roundtrip air ticket		400
ground transportation		100
lodging 3 days @ \$100		200
per diem 3 days @ \$35		70
conference registration		<u>150</u>
SUBTOTAL TRAVEL	1,200	2,180
<u>Taxonomic Consultants</u>		
year 1: 40 hrs @ \$50/hr	2,000	
year 2: 20 hrs @ \$52.50/hr		1,050
<u>Miscellaneous</u>		
Software, literature, shipping, copying	800	840

Schedule

Complete preparations and begin sampling	by 1 month	from start of project
Submit progress report	at 12 months	"
Complete sampling	by 16 months	"
Complete analysis	by 18 months	"
Prepare draft report	by 20 months	"
Complete external review	by 21 months	"
Prepare final report	by 23 months	"
Prepare journal submission	by 24 months	"

Third Party Impacts

No third party impacts are anticipated.

San Francisco Estuary Institute

The San Francisco Estuary Institute (SFEI) is a non-profit research institute charged with fostering scientific understanding of the Estuary. The creation of SFEI responds to a recommendation of the Comprehensive Conservation and Management Plan (CCMP) for the San Francisco Estuary adopted by the Governor of California and the Administrator of the U.S. Environmental Protection Agency in late 1993. The Institute's 22 staffmembers provide an interdisciplinary team of scientists, education specialists, data analysts, and support personnel. The Institute also employs graduate students and undergraduate interns from area Universities. The Institute conducts or provides science support for four major programs: the San Francisco Estuary Regional Monitoring Program for Trace Substances, the Bay Area Wetlands Ecosystem Goals Project, the Bay Area Watershed Science Program, and the Biological Invasions Program.

SFEI's Biological Invasions Program researches issues of scientific and policy interest related to the introduction of nonindigenous species into marine and freshwater ecosystems. The research program is directed toward five objectives: (1) assisting efforts to prevent future invasions through scientific and policy research on vectors and the control of vectors; (2) developing an effective regional monitoring program to identify new invasions and track the spread of nonindigenous species that are present in the region; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; (5) developing, prioritizing and assessing methods to control nonindigenous species that are present in the region.

Current projects of the program include:

- Developing methods for prioritizing efforts to control exotic marsh plants in the Estuary.
- Assessing the potential range and abundance of zebra mussels in California waters.
- Research on the introduction of organisms in the marine baitworm trade.
- Research on the invasion of the California coast by a Japanese foraminifer.
- Developing a regional monitoring plan for exotic organisms.
- Modelling the effect of invasion "incubators" on the success of obligate sexually-reproducing invaders.
- Review of open coast invasions, with a case study of the invasion of the Southern California Bight by a New Zealand sea slug.

Andrew N. Cohen
Environmental Scientist
San Francisco Estuary Institute

Dr. Cohen holds an M. S. and Ph. D. degrees in Energy and Resources from the University of California at Berkeley. He is the author of the 1995 USFWS report on nonindigenous species in the San Francisco Estuary and of papers on other aspects of marine and aquatic invasions. Dr. Cohen also worked on and written about water system planning and economics, public health and contaminants in fish, and environmental mitigation; and has written articles and books for the general public on water and environmental policy and history. His work on invasions in the Estuary was profiled last year in the *New York Times* Science Page, and he was recently nominated to co-chair the Western Regional Panel on Aquatic Nuisance Species. He currently directs the San Francisco Estuary Institute's research program on biological invasions.

Recent Publications

Carlton, J. T. and A. N. Cohen. Episodic global dispersal in shallow water marine organisms: The case history of the European green crab *Carcinus maenas*, *J. Biogeogr.* (in press).

Cohen, A. N. The exotic species threat to California's coastal resources, *Proc. California and the World Ocean '97 Conference*, March 24-27, 1997, San Diego CA (in press).

Cohen, A. N. The invasion of the estuaries. *Proc. 2nd International Spartina Conf.*, Mar. 20-22, 1997, Olympia WA (in press).

Carlton, J. T. and A. N. Cohen. Periwinkle's progress: The Atlantic snail *Littorina saxatilis* establishes a colony on Pacific shores, *Veliger* (in press).

Cohen, A. N. and J. T. Carlton. Transoceanic transport mechanisms: The introduction of the Chinese mitten crab *Eriocheir sinensis* to California, *Pac. Sci.* 51(1): 1-11, 1997.

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Bruce E. Thompson
Senior Scientist
San Francisco Estuary Institute

Dr. Thompson received his M. A. at the Moss Landing Marine Laboratory, and his Ph. D. in Biological Sciences from the University of Southern California in 1982, working in benthic marine ecology. He worked at the Southern California Coastal Water Research Project for 11 years prior to joining the staff of SFEI in 1992. His research has included field and laboratory studies of the ecology of benthic communities and species off southern California, and how they are affected by contamination. He was also involved in the development of regional monitoring programs in southern California, and is now the Program Manager for the San Francisco Estuary Regional Monitoring Program at SFEI.

NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME

SAN FRANCISCO ESTUARY INSTITUTE

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California.

OFFICIAL'S NAME

Margaret R. Johnston

DATE EXECUTED

July 25, 1997

EXECUTED IN THE COUNTY OF

Contra Costa County

PROSPECTIVE CONTRACTOR'S SIGNATURE

PROSPECTIVE CONTRACTOR'S TITLE

Executive Director

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

San Francisco Estuary Institute